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Sensitivity of the Market Equilibrium Reserve Margin to Potential Changes in the ORDC

Prepared for Calpine

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Scope

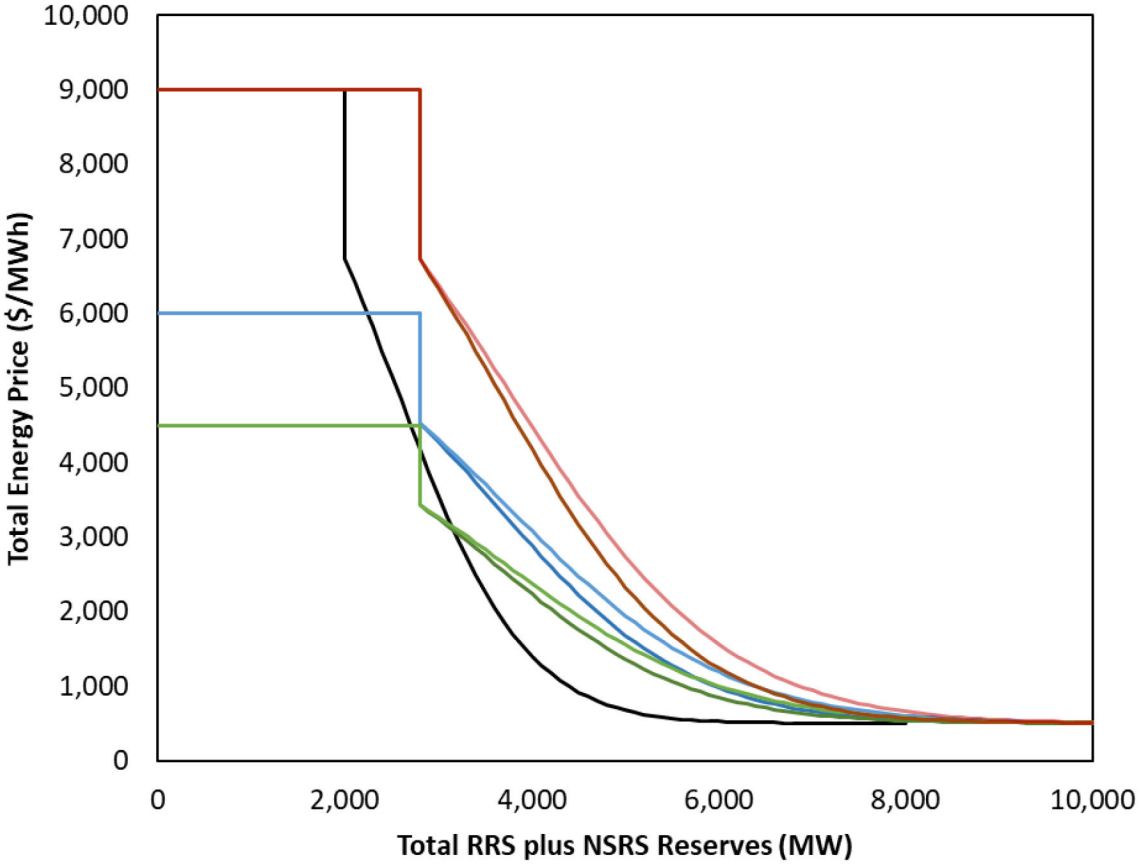
- **Calpine requested analysis of alternatives to current Operating Reserve Demand Curves (ORDCs)**
- **We analyzed implications for:**
  - Market Equilibrium Reserve Margin (MERM)
  - Physical Reliability (LOLE)
  - Wholesale Price
- **Multiple data sources used to construct Strategic Energy Risk Valuation Model (SERVM) inputs**
  - ERCOT's publicly published data
    - Renewable synthetic generation profiles
    - Generator data from Capacity, Demand and Reserves Report (CDR)
    - System info including ORDC, reserve targets, etc.
  - Astrapé's proprietary U.S. dataset
    - Class average equivalent forced outage rates (EFORs)
    - Loadshapes developed from Federal Energy Regulatory Commission (FERC) data

Methodology

- **Our sensitivity analyses each assume one ORDC per year**
  - It replaces 4 ORDC curves for 2 types of operating reserves to 1 ORDC curve for 2 operating reserves
  - The ORDC curve is still based on a Mu/Sigma value that applies to the online and the offline reserves
- **Our simulations follow a similar analysis to ERCOT's 2020 Reserve Margin Study**
  - 2024 market conditions
  - Solar and wind penetration increased to match May 2021 CDR projection for 2024
  - Vary installed combined cycle (CC) capacity to identify the market equilibrium where new entrants just earn their levelized cost of new entry (CONE)
  - CC CONE estimated at $129.8/kw-yr*

**derived from values provided here: https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf*

Alternative ORDC Curves



Identifier	ORDC Description		
	Value of Lost Load (VOLL) ($/MWh)	Minimum Contingency Level (MCL) (MW)	Mu and Sigma Adjustment Factor (%)
	9,000	2,000	N/A
	9,000	2,800	+50%
	9,000	2,800	+70%
	6,000	2,800	+50%
	6,000	2,800	+70%
	4,500	2,800	+50%
	4,500	2,800	+70%

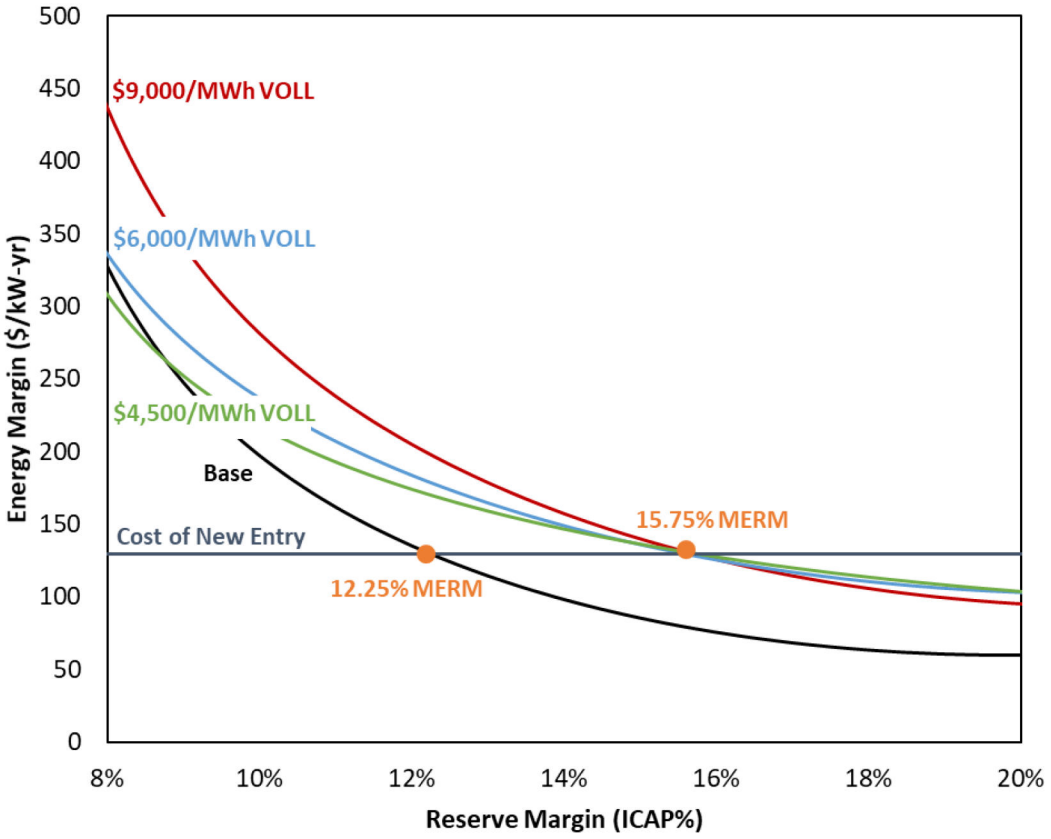
**The curves shown reflect a static $500/MWh energy price plus ORDC adder as a function of reserves. However, in the simulations the energy price is calculated dynamically each hour.*

*** RRS = Responsive Reserve Service; NSRS = Non-Spinning Reserve Service; MW= Megawatt; MWh = Megawatt Hour*

Market Equilibrium Reserve Margin

- **Tuned ORDC shapes to achieve MERM at 0.1 LOLE RM**

VOLL ($/MWh)	Minimum Contingency Level (MCL) (MW)	Forecasted ORDC Mu/Sigma Adjustment Factor (%)	MERM (%)
9,000	2,800	44.5%	15.75%
6,000	2,800	62.5%	15.75%
4,500	2,800	79.5%	15.75%



*** RM = Reserve Margin; ICAP = Installed Capacity; kW = Kilowatt*

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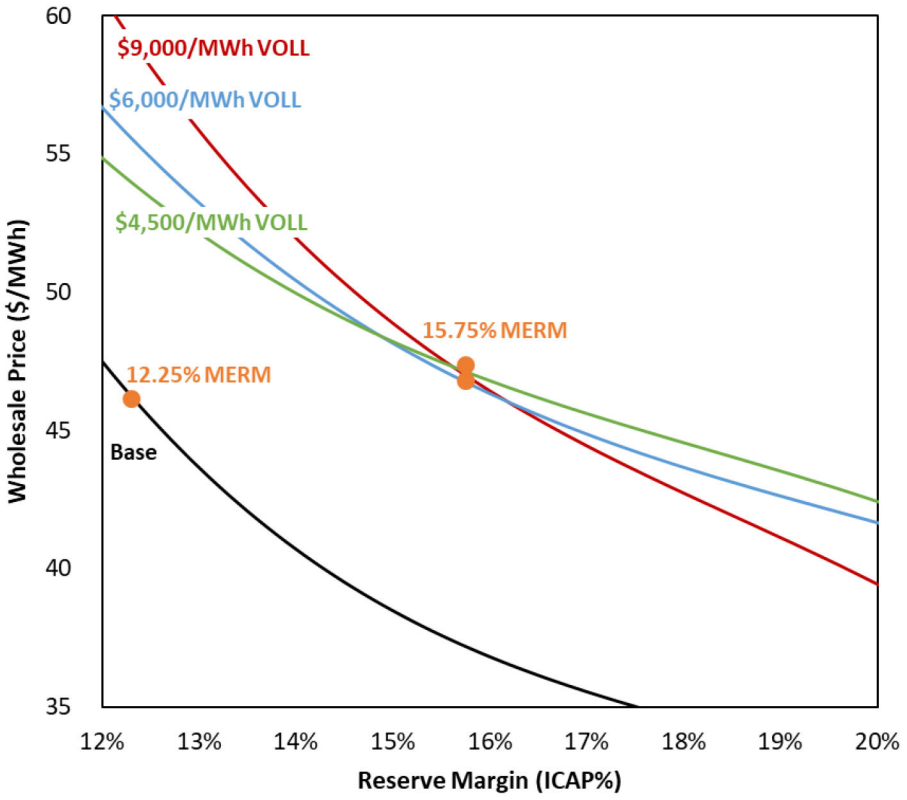
Wholesale Price

VOLL ($/MWh)	MERM (%)	Wholesale Price ($/MWh)	Wholesale Price Increase Over Base ($/MWh)	Wholesale Price Increase Over Base (%)	LOLE (Events Per Year)
Base	12.25%	46.49	-	-	0.5
9,000	15.75%	46.99	0.50	1.07%	0.1
6,000	15.75%	46.74	0.25	0.54%	0.1
4,500	15.75%	47.14	0.65	1.41%	0.1



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Considerations

- **More nuanced ORDC adjustments are likely to produce more desirable economic outcomes versus linear shifts in Mu and Sigma**
- **More rigorous analysis will be required to confirm energy margins and wholesale prices for high ORDC sensitivities**
  - Revenue shift between resource classes should be analyzed in more detail between scenarios

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Mr. Carden is the Director of Astrapé Consulting, an energy consulting organization with a focus on resource planning. Under Kevin's leadership, Astrapé Consulting has provided consulting services to utilities nation-wide Kevin holds a B.S. in Industrial Engineering from the University of Alabama. Kevin holds a U.S. patent in Generation Reliability Modeling techniques (#7698233).

Mrs. Dombrowsky is a senior consultant at Astrapé Consulting. Alex has worked on reserve margin studies, renewable integration studies, and ELCC studies for clients around the world. Alex holds a B.S. in Chemical Engineering from the University of Alabama.

About Astrapé

Astrapé Consulting is the exclusive licensor of the SERVM model and has been responsible for developing and marketing the model since 2005. Astrapé Consulting has extensive experience in resource adequacy modeling, calculating the capacity value of energy-limited and non-dispatchable resources, as well as capturing economic metrics for regulated utilities, regulators, and independent system operators.

Astrapé Consulting has provided electric system planning services and resource adequacy studies for many of the largest utilities and regulators in the US and Europe

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